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EFFECTS OF ENDURANCE TRAINING ON GONADAL FAT PAD AND VENTRICULAR MASS IN RAT

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Abstract. It has been reported that gonadal fat pad correlates well with the body fat in mice. The effects of endurance training on gonadal fat pad and also on ventricle mass in rat were tested in this study. Eight week treadmill training increased the endurance time and distance run in trained rats compared with sedentary rats. Endurance training decreased the weight of the left gonadal fat pad and also proportional gonadal fat pad in rats. However, Lee index, weights of the ventricles, kidneys, and testicles were not affected. The decrease in gonadal fat pad by eight week treadmill training in rat, suggests that endurance training may affect the body composition in favor of other tissues than adipose tissue probably by increasing the consumption of fats rather than carbohydrates to provide energy. Lee index, which is an obesity index used in rodents, may not be sensitive enough to detect small alterations in body fat in rats reflected as decreased gonadal fat pad by training in our study. Ventricular function should have improved to increase endurance by 8 week treadmill training not necessarily increasing the ventricular mass in our study. ***(Biol.Sport 24:265-273, 2007)***

Key words: Endurance training - Gonadal fat pad - Body composition - Ventricular mass

Introduction

Assessment of body composition provides additional information beyond the basic measures of height and weight to both coach and the athlete. Most scientists have adopted two-component model for body composition that includes fat mass and fat free mass. Fat mass is the percentage of total body mass composed of fat, also called relative body fat, while fat-free mass refers to all of the body's nonfat tissue, including bone, muscle, organs, and connective tissue [24]. Body fat is a major concern of athletes. It is known that adding more fat to the body just to

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increase the athlete's weight is generally detrimental to performance and less fat generally leads to better performance [13,24]. The fact that male runners normally have much less relative body fat than female runners is thought to be one of the most important reasons for the differences in running performance between elite male and female distance runners [23].

Endurance training affects the priority of the energy resources to be used by the skeletal muscles. In addition to its greater glycogen content, endurance-trained muscle contains substantially more fat stored as triglyceride than untrained muscles do. A 1.8-fold increase in muscle triglyceride content has been reported after only 8 week of endurance running [3]. Furthermore, activities of many muscle enzymes, responsible for the β oxidation of lipids, increase with endurance training. For example, prolonged submaximal training (cycling 5-6 times per week for 2 h a day at 68% VO_2peak for 11 weeks) increases beta-hydroxyl-CoA dehydrogenase activity in human vastus lateralis muscle [6]. These adaptations enable endurance-trained muscle to burn lipids more efficiently, reducing the demands placed on a muscle glycogen supply. Thus, it may be hypothesized that endurance training may decrease body fat due to the consumption of fat as the primary source of energy.

There are some studies investigating the effects of endurance training on body fat. It is reported that exercise training consisting of an 8-week aerobic exercise decreases visceral subcutaneous adipose tissue area and increased mid-thigh muscle cross-sectional area determined by magnetic resonance imaging, with no modification in body weight, concluding that training decreases abdominal fat depots and improves muscular mass [1]. A favorable influence of 4 months of physical training on visceral and subcutaneous abdominal adipose tissues in obese children with type II diabetes mellitus has been reported [9]. On the other hand, no change in body fat percentage and body weight by 6 weeks of aerobic exercise in patients with type 2 diabetes mellitus has also been reported [12].

It has been reported that gonadal fat pad correlates well with the body fat determined by time consuming drying and extraction procedures in normal mice [17]. To our knowledge no study reports the effect of endurance training on body fat in rats. Therefore, the effect of endurance training on gonadal fat pad was primarily tested in this study. Additionally, its effect on ventricle mass was also evaluated, because there are studies reporting increased [22] or unchanged [2,5,19] heart weights in rats by endurance training. We have previously reported the attenuation of acute exercise induced oxidative stress in erythrocytes by endurance training in these rats [14].

Materials and Methods

Animals and groups: Fifty-six male rats (Sprague-Dawley strain), fed with standard laboratory chow and water, were used in the study. Animal experimentations were approved by the Ethical Committee of the Ataturk University and carried out in an ethically proper way by following the guidelines provided.

Training and acute exhaustive exercise: Male rats (Sprague-Dawley strain, n=56) were equally divided into trained (TR, TE) and untrained groups (UR, UE) at random. Both groups were further divided into two groups where the rats were studied at rest (TR and UR) and immediately after exhaustive exercise (TR, UE). After familiarizing the rats to the treadmill, endurance training began with gradual increases in training speed and time such that rats were running 2.1 km/h at the fourth week. Training continued 1.5 h/d, 5 days a week for 8 weeks. During the eighth week of the training program, the UE subgroup was also accustomed to treadmill running 1.0-1.2 km/h, 15 min/day, for 5 days before sample collection. This regimen was used to ensure that untrained rats could also tolerate the acute exhaustive exercise without having a significant training effect.

Two rats in the training group, which could not run well, were excluded from the study. At the end of the training period, half of the rats were randomly selected into the acute exercise group. In acute exhaustive exercise, running speed was 1.2 km/h (10% uphill gradient) for the first 10 min, after that, the speed was increased gradually to 2.1 km/h at 95th min, and kept constant until the rats were exhausted. The loss of the righting reflex when the rats were turned on their backs was the criterion of exhaustion. Body weights were weighed every week for 8 weeks.

Determination of the Lee index and weighing the organs: At the end of the study, the animals were anesthetized (by 20 mg/kg i.p. ketamine-HCl, Ketalar flacon, Eczacibasi, Istanbul), weighed, their nasoanal lengths were measured, and the Lee index, an obesity index used in rodents, was calculated using the following formula [17]

$$\text{Lee index} = \text{weight } (g^{0.33}) \div \text{nasoanal length (mm)}.$$

The heart was taken out of the body after thoracotomy, the auricles and vessels were removed and the ventricles (consisting of both right and left ventricles) were weighed. The right gonadal fat pad was carefully dissected out and weighed. Both testicles were weighed with their capsules. Both of the kidneys were also weighed after removing their fibrous capsule.

Statistics: Results given are means ±SD. The group means were generally compared by using Student's t test. Paired t test was also used to compare the body weights before and after 8 weeks of training. P less than 0.05 was considered significant.

Results

Body weight: Body weights of both trained and untrained groups were increased during the 8 weeks of study period (Table 1). Although the rats randomly selected for the training, they were slightly heavier than the untrained group in the beginning. However, there was no difference between the increase in body weights in untrained and trained groups during the study (Table 1).

Table 1
Body weights of untrained and trained rats in the beginning and at the end of the study. The results are means ±SD

Group	Untrained (UR and UE)	Trained (TR and TE)
n	28	26
Body weight (g) in the beginning of the study	192±35	219±31*
Body weight (g) at the end of 8 weeks	237±46 #	268±38*#
Difference in body weights (g) between the beginning and at the end of 8 weeks	48±17	52±25

*p<0.05, unpaired t test, difference between trained and untrained groups;
# p<0.001, paired t test, difference in body weights between the beginning and at the end of 8 weeks.

Eight week treadmill training decreased the weight of the left gonadal fat pad and also proportional gonadal fat pad in rats (Table 2). However, Lee index, weights of ventricles, kidneys, and testicles were not affected by training (Table 2).

Endurance: Treadmill training increased the endurance time and distance run in trained rats compared with sedentary rats (Table 3).

Table 2
Weight of the left gonadal fat pad, proportional gonadal fat pad, ventricular weight and proportional ventricular weight, weight of both kidneys and proportional renal weight, weight of both testicles, and proportional testicular weight, and length and also Lee index of untrained and trained rats. The results are means ±SD

Group	Untrained (UR and UE)	Trained (TR and TE)
n	28	26
Weight of the left gonadal fat pad (g)	$8.80 \pm 2.32 \times 10^{-2}$	$6.5 \pm 1.79 \times 10^{-2}$*
Proportional gonadal fat pad [(left gonadal fat pad/body weight)*100]	$3.65 \times 10^{-2} \pm 0.75 \times 10^{-2}$	$2.43 \times 10^{-2} \pm 0.05 \times 10^{-2}$*
Ventricular weight (g)	0.75±.16	0.78±0.13
Proportional ventricular weight [(ventricular weight/body weight)*100]	0.31±0.05	0.31±0.03
Weight of both kidneys (g)	1.55±0.38	1.56±0.24
Proportional renal weight [(weight of both kidneys/body weight)*100]	0.63±0.137	0.61±0.063
Weight of both testicles (g)	2.13±0.28	2.08±0.49
Proportional testicular weight [(weight of both testicles/body weight)*100]	0.88±0.175	0.82±0.161
Length (cm, at the end of 8 weeks)	21.67±0.92	22.16±1.03
Lee index	$2.8 \times 10^{-2} \pm 0.12 \times 10^{-2}$	$2.8 \times 10^{-2} \pm 0.07 \times 10^{-2}$

*p<0.001, Student's t test, difference between trained and untrained groups

Table 3
Endurance time and distances run to exhaustion in untrained and trained rats

Group	Untrained-acute exhaustive exercise (UE)	Trained-acute exhaustive exercise (TE)
n	14	13
Time to exhaustion (min)	114.86±8.92	170.08±26.43*
Distance run (m)	2455.71±267.52	4112.31±793.01*

* $p<0.001$, Student's t test

Discussion

Gonadal fat pad decreased while Lee index, weights of the ventricles, kidneys, and testicles were not affected by training. Although our result is not directly comparable, decrease in gonadal fat pad by 8 week treadmill training agrees with the findings of Boudou *et al.* in diabetic men [1] and Gutin and Owens in obese diabetic children [9]. Boudou *et al.* reported that exercise training consisting of an 8 week aerobic exercise decreased visceral subcutaneous adipose tissue area and increased mid-thigh muscle cross-sectional area determined by magnetic resonance imaging, with no modification in body weight, concluding that training decreases abdominal fat depots and improves muscular mass [1]. Gutin and Owens reported that 4 months of physical training had a favorable influence on visceral and subcutaneous abdominal adipose tissues in obese children with type II diabetes mellitus [9]. On the other hand, Ishii *et al.* could not find a change in body fat percentage and body weight by 6 weeks of aerobic exercise in patients with type 2 diabetes mellitus [12]. While there was no difference in body weight increases between trained and untrained rats, the decrease in gonadal fat pad in trained rats in this study, and also the decreases in fat tissue in other human studies in general [1,9] suggest that body composition should have been changed in favor of other components such as proteins in which muscles are rich. Unaffected Lee index while the gonadal fat pad decreases in our study suggests that this index may not detect small alterations in the body fat in normal rats. It is reported that Lee index does not correlate well with body fat in normal mice agreeing with our result in normal rats, while it correlates well with body fat in mice with obesity [17].

Our finding, increased endurance time due to physical training in normal rats, agrees with various studies in literature. It is reported that physical training as applied by running on treadmill [4,18,19] or swimming [22] in normal rats, and also by running on treadmill in diabetic rats, increases the endurance.

It is well known that endurance training increases maximal oxygen consumption (VO_{2max}) [7,15]. Radak *et al.* have recently shown that endurance training increases maximal oxygen consumption in rats [16] confirming previous reports [2]. Most of the increase in VO_{2max} results from the increase in stroke volume and some part comes from the increase in oxygen uptake by skeletal muscle. The increase in endurance to exhaustion in trained rats suggests that the stroke volume is increased probably with increased oxygen uptake in skeletal muscles. An increase in heart weight in rats by swim training (gradually increase reaching 90 min/day after 6th week, 5 days/week, for 10 weeks) without altering heart to body weight ratio have been reported [22]. However, there was no difference between ventricular weights of untrained and trained groups in our study. Parallel to our finding, no change in ventricular mass or heart weight in rats [2,5,19] and rabbits [21] was reported in various endurance training studies. Despite unaltered ventricular mass, increased endurance may mean that ventricular function should have improved by endurance training to increase stroke volume, not necessarily increasing the ventricular mass in our study.

Regularly performed endurance exercise induces major adaptations in skeletal muscle. It is recently confirmed that endurance training increases the capillary vasculature also in human skeletal muscle [20]. The activities of the enzymes of the mitochondrial electron transport chain and also the number of mitochondria increase by endurance training, which improve the capacity of the muscle to produce energy aerobically [10,11]. The activities of many muscle enzymes responsible for the β oxidation of lipids also increase with endurance training. For example, prolonged submaximal training (cycling 5-6 times per week for 2 h a day at 68% VO_2peak for 11 weeks) increases beta-hydroxyl-CoA dehydrogenase activity in human vastus lateralis muscle [6]. These adaptations result in a shift in trained muscle to a greater reliance on fat as a fuel with a concomitant reduction in glycolytic flux. The reliance on fat rather than carbohydrate as a fuel in endurance trained rats [11] may explain the decrease in the amount of the left gonadal fat pad in our study.

To conclude, our result, decrease in gonadal fat pad by eight week treadmill training in rat, suggests that endurance training may affect the body composition in favor of other tissues than adipose tissue probably by increasing the consumption of fats rather than carbohydrates to provide energy. Lee index may not be sensitive enough to detect small alterations in body fat in rats reflected as decreased gonadal fat pad by training in our study. Ventricular function should have improved to increase endurance by 8 week treadmill training not necessarily increasing the ventricular mass in our study.

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